

# Health Physics Department. Annual Progress Report 1 Jan - 31 Dec 1986

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# Health Physics Department Annual Progress Report

1 January–31 December 1986

Risø National Laboratory, DK-4000 Roskilde, Denmark

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# HEALTH PHYSICS DEPARTMENT
Annual Progress Report
1 January - 31 December 1986

Abstract. The report describes the work of the Health Physics Department at Risø during 1986. The activities cover dosimetry, instrumentation, radioecology, risk by nuclear activities and nuclear emergency preparedness. Lists of staff and publications are included.

The emphasis in the report has been placed on scientific and contractual work. However, service functions do constitute a substantial work load for the department.

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## 1. INTRODUCTION

The Health Physics Department has the responsibility for some general functions at Risø: dosimetry, instrumentation, environmental monitoring, and health physics preparedness. The section for applied health physics, however, is part of the Safety Department.

The department is also responsible for more extensive education in health physics. Besides courses for the staff at Risø this includes shorter courses and lectures for nurses, fire brigade inspectors, naval officers and many others. Further, many of the staff members give lectures or otherwise assist in educational programmes at universities and give informative talks to societies and clubs.

For society at large, the department assists in answering questions and making statements or reports for the government and the central administration. In 1986 this work surged as a result of the Chernobyl disaster.

Finally, it should be mentioned that the department is represented in a number of international committees, the most important of which are listed in Appendix 2.

## 2. DOSIMETRY AND INSTRUMENTATION

### 2.1. Personal dosimetry

Risø's personal dosimetry service covers the individual monitoring of the personnel at Risø and the Niels Bohr Institute Tandem Accelerator. All workers and visitors staying at Risø for a period of more than two days are supplied with the Risø standard beta/gamma personal TLD badge. Additional dosemeters, e.g. fast neutron films, quartz fibre pen dosemeters, extremity dosemeters and criticality dosemeters are supplied according to special requirements. Urine samples are routinely collected in accordance with an established programme.

In 1986 approximately 2200 persons were monitored; of these 169 persons received doses above the registration level for external doses of 0.2 mSv (20 mrem). The total dose (collective dose equivalent) registered to the monitored personnel was 0.30 man Sievert (30 man rem). 15 persons received internal doses caused by intake of tritiated water. The contribution to the total dose from internal doses was 0.007 man Sievert (0.7 man rem). Figure 1 shows the distribution of the levels of the registered doses for 1986.

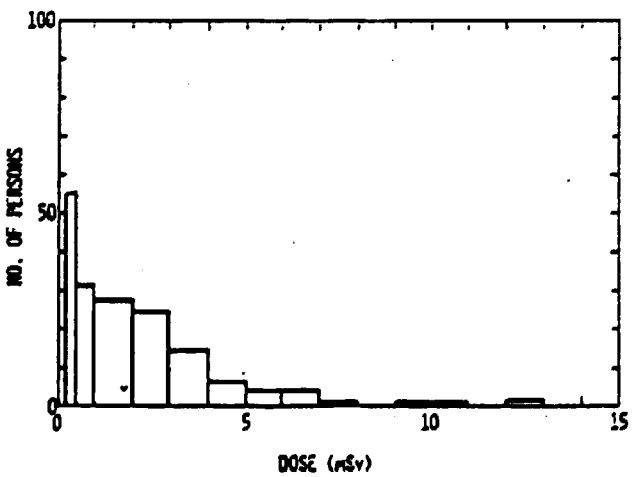


Fig. 1. Distribution of yearly whole body doses (effective dose equivalent) from 1986 for the Risø personnel.

## 2.2. Beta dosimetry

The investigations of energy and angular responses of TL dosemeters to beta radiations have continued. Different types of TL dosemeters have been investigated and the results compared with extrapolation chamber measurements. The conclusion of the investigation emphasizes the importance of using thin detectors for skin dose assessment.

In co-operation with NRPB, UK, and PTB, Germany, a project has been initiated concerned with the determination of conversion factors for estimating the new ICRU dose equivalent quantity H'(0.07) for beta ray exposures from different angles of radiation incidence. The investigation will include different measurement methods.

The laboratory has contributed to a CEC beta intercomparison programme by irradiating approximately 600 dosemeters from 34 different European laboratories. The group has assisted CEC in planning the intercomparison programme including the arrangement of a seminar to be held in Bologna in 1987.

## 2.3. Nuclear track detectors

The image analysis system described in the annual progress report for 1985 (Risø-M-2557) was further developed and used in connection with the radon monitoring and neutron dosimetry work. In the work for a master's thesis, aiming at α-particle spectrometry applications, the size and shape of etched pits in CR-39 plastic were studied after irradiation with α-particles of varying energy and angle of incidence. In a programme of joint European/US/Canadian neutron irradiations a number of CR-39 track detectors were irradiated to neutrons of different energies at five laboratories. The results will be evaluated and reported in 1987.

## 2.4. Natural radiation in dwellings

A nationwide investigation of natural radiation in Danish dwellings was carried out in 1985-86 in co-operation with the National Institute of Radiation Hygiene. The investigation comprised about 500 dwellings. They were monitored for 6 months, half of them during summer-time, and the other half during winter-time. Integrating measurements of radon were made with Risø cup dosemeters equipped with CR-39 track detectors (2 dosemeters in each house), and measurements of external gamma radiation were made with thermoluminescence dosemeters. The results are in accordance with the general observations made during a pilot survey in 1983-84, e.g. on an average the radon levels are higher in detached houses than they are in apartment buildings, and the highest radon levels are observed during the winter half-year. The results are being analysed in detail and they will be reported in 1987.

Another project, supported by the Commission of the European Communities, deals with some of the factors which influence the radon concentration in detached houses. The object of the study is a cluster of 16 almost identical houses in which significant differences in indoor radon concentrations have been found. The houses were built in 1956-57 as dwellings for Risø employees.

The investigations comprise indoor measurements of radon concentrations, temperature, absolute and differential air pressure, and air-exchange rate, as well as studies of the characteristics of the soil in the area.

Passive integrating measurements of indoor radon concentrations were carried out throughout 1986 in consecutive two-month periods. The average radon concentration for the calendar year was found to be:

- below 100 Bq/$m^3$ for 5 houses
- between 100 and 200 Bq/$m^3$ for 5 more houses, and
- above 200 Bq/$m^3$ for the remaining 6 houses

The range was from about 50 to about 360 Bq/$m^3$ (yearly average).

One house, that was vacant for about three months, was equipped with continuous radon monitors, one monitoring the air in the living-room, another in a bedroom, and a third in a district-heating duct. Simultaneously, the outdoor air and the radon exhalation from the soil surface were monitored. Hourly data from the five radon monitors, four thermocouples, one absolute air-pressure sensor, and one differential air pressure sensor, were recorded by a datalogger throughout the period. In addition, the air-exchange rate was measured by the $SF_6$ tracer gas technique.

The soil investigations were carried out by the Department of Electrophysics of the Technical University of Denmark. They have shown that the soil in most of the area consists of moraine clay, but there are also deposits of sand and gravel with a higher permeability. 48 samples of soil from the upper parts of the bore holes have shown a radon emanation varying from 5 to 15 radon atoms$\cdot kg^{-1} \cdot s^{-1}$, which is normal for Danish soil.

## 2.5. Environmental dosimetry

As part of the environmental monitoring programme carried out by Risø, gamma background exposure levels at different sites in Denmark are routinely measured by means of LiF TLD-700 dosemeters. The integration times used are 6 months for zones surrounding the Risø facilities and 12 months for selected sites elsewhere in the country. The mean exposure levels, expressed in units of absorbed dose in air per hour, for different parts of Denmark in 1985 are given in the following table:

| Location | Mean exposure rate (nGy/h)* |
|---|---|
| Risø area | 77 |
| Zealand and islands | 82 |
| Jutland | 71 |
| Bornholm (Baltic island) | 97 |

*) cosmic component is included

There is a need for reliable passive dosemeters that can estimate the doses from effluent gamma emitters with a wide range of energies, and give information on the energy distribution of the environmental gamma radiation.

For this purpose a new environmental TL dosemeter with spectrometric properties was developed and tested in 1986. Experimentally obtained energy responses from a TL dosemeter combination consisting of five $CaSO_4$:Dy dosemeters with different filters were used as input for the SAND II computer code (Spectrum Analysis by Neutron Detectors) that had been adapted to evaluate the energy distribution of environmental gamma radiation and related doses.

Dosemeters have been exposed to natural radiation from the environment as well as to radiation from artificial sources. The estimated gamma-ray energy distributions and doses were tested against results from measurements made with a sodium iodide spectrometer and a high-pressure ionisation chamber.

## 2.6. Phantom for internal dosimetry

The work on experimental validation of internal dosimetry calculations is in progress. Experiments have shown that tissue

equivalent liquids rather than water should be used both for the organ and body tissues. A suitable granulate will be used for lung tissue.

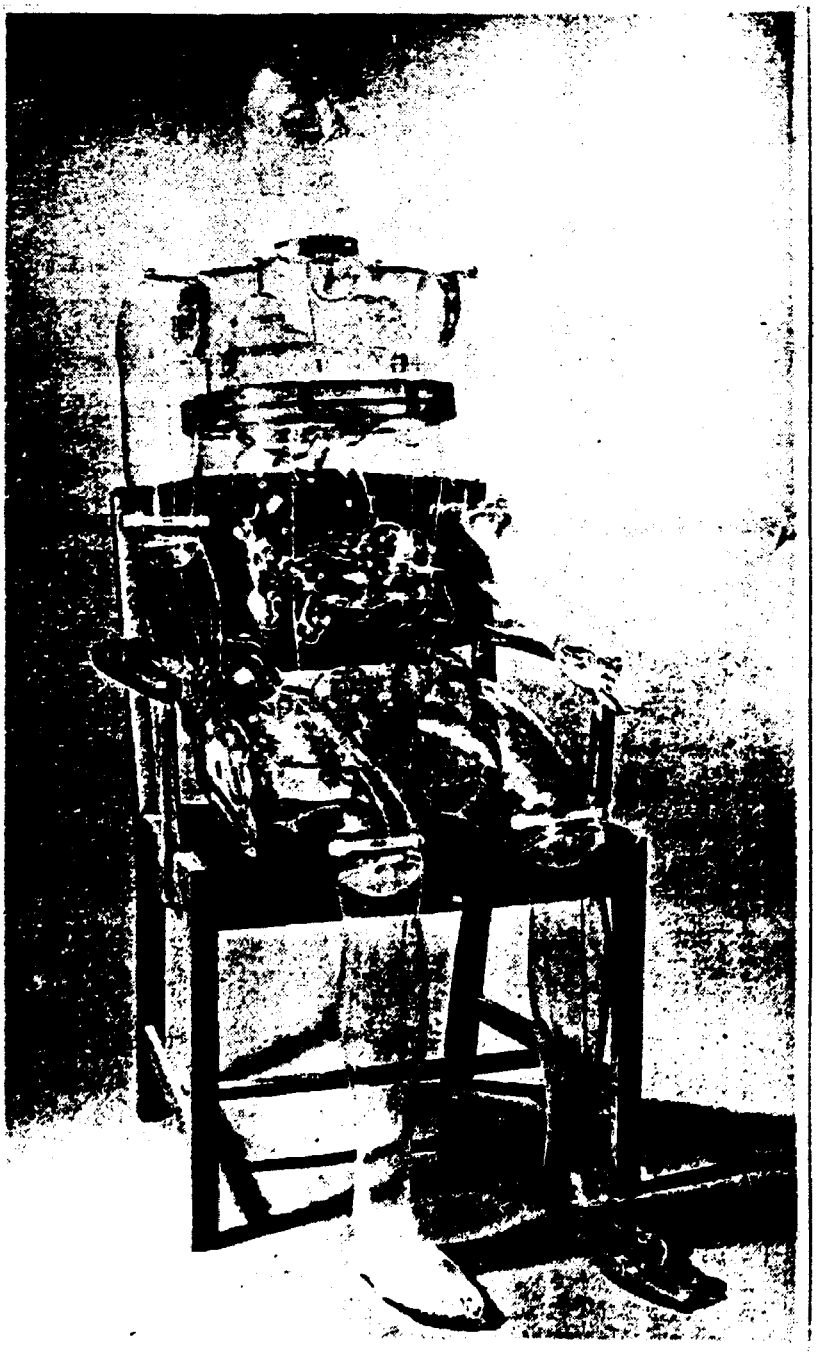

Fig.2. Internal-dosimetry phantom.

## 2.7. Instrument service

The health physics instrument service covers routine calibration and maintenance of approximately 650 health physics survey instruments of which approximately 50 are positioned outside Risø as part of emergency arrangements. In addition, the instrumentation group is responsible for the operational performance and calibration of area- and effluent monitoring systems installed at nuclear facilities at Risø.

## 2.8. Gas-flow multicounters for low-level beta counting

A five-sample anticoincidence proportional multicounter equipped with 60 mm diameter sample counter windows was developed for measuring alpha and beta activity from smear tests and put into operation at the Hot Cell facilities. The counter system is prepared for the extension of an additional five-sample unit ending up with a total counting capacity of ten samples to be measured simultaneously. A total of 20 individual counting channels (10 x alpha plus 10 x beta) are thus incorporated.

Five anticoincidence GM multicounter systems for the measurement of radioecological beta samples were produced in 1986 and delivered to Institute Petten, Holland; ENEA, La Spezia, Italy; ENEA, Bologna, Italy; University of Lancaster, U.K.; and Laboratorio Nacional de Engenharia, Sacavem, Portugal.

## 2.9. TL instrumentation

A cooperative effort between Risø and Alnor OY, Finland, on the development of a new automated TL system for personal- and environmental monitoring included a detailed testing at Risø of a prototype instrument. The development work is also focusing on meeting international requirements such as ANSI and ICRU recommendations. A prototype TL badge was tested for energy response and angular dependence and the overall TL system was performance

tested. One new Alnor reader was delivered to Risø to replace an old Risø-produced model used for routine measurements of environmental doses.

The cooperative work between Risø and the National Institute of Radiation Hygiene was continued with development of a computer controlled TL reader for routine processing of large numbers of TL dosemeters. The reader that uses hot $N_2$-gas heating was hardware tested and software is being developed and tested.

A fully automated TL reader system for TL dating equipped with vacuum chamber and beta irradiator was constructed and delivered to University of Cambridge, U.K., as part of a joint CEC TL dating project.

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# 3. RADIOECOLOGY

## 3.1. Environmental radioactivity

The studies of environmental radioactivity were continued in 1986. Strontium-90 was determined in samples taken from different parts of the country of precipitation, ground water, drinking water, seawater, dried milk, grain, bread, potatoes, vegetables, fruit, total diet, and human bone. Furthermore, $^{90}Sr$ was determined in local samples of air, rainwater, marine sediments, grass, sea plants, fish, and meat. Cesium-137 was determined in air, precipitation, seawater, sediments, milk, grain products, potatoes, vegetables, fruit, total diet, sea plants, fish, and meat. Estimates of the mean content of radiostrontium and radiocesium in the human diet in Denmark were reported. Tritium was determined in precipitation, fresh water and seawater. Plutonium and americium were measured in seawater, sediments, sea plants, and mussels.

The Chernobyl accident (cf. 5.1) in April 1986 resulted in a substantial supplementary monitoring programme for Denmark, the Faroe Islands, and Greenland. The radionuclides of utmost importance were $^{137}Cs$, $^{134}Cs$ and $^{131}I$. But a variety of samples were also analysed for $^{90}Sr$, $^{89}Sr$, $^{239,240}Pu$, $^{238}Pu$, $^{241}Am$, $^{242}Cm$, and $^{244}Cm$.

The $\gamma$-background was measured regularly by TLD, ionization chamber and on site $\gamma$-spectroscopy at locations around Risø, at ten of the State experimental farms along the coasts of the Great Belt and around Gylling Næs.

The marine environment at Barsebäck and Ringhals were monitored for $^{137}Cs$ and corrosion products ($^{58}Co$, $^{60}Co$, $^{65}Zn$, $^{54}Mn$).

Samples of various foods and drinking water from Greenland and the Faroes were analysed for $^{90}Sr$ and $^{137}Cs$.

## 3.2. Dynamic models of the human food-chain

Two dynamic models, RIDYFOM and SPOP, of the human foodchain in the terrestrial environment were constructed and tested. RIDYFOM models the transfer from air to soil and vegetation and further to foodstuffs, and SPOP models more specifically the root uptake from soil to vegetation.

A computer program system was obtained from the University of Lund, Sweden, to facilitate the correct adjustment of transfer coefficients of the models. The computer program works on compartment models and adjusts specified transfer coefficients of these models so as to obtain the best agreement (in a least-squares sense) between measurement results and model predictions. We have implemented and successfully tested the program system at the Risø computer centre.

The RIDYFOM and SPOP models were tested in an international benchmark study with other similar models of the human foodchain of the terrestrial environment. The results of the model calculations displayed a considerable scatter and it was recognised that the main reason for this was the choice of different transfer coefficients in the models. Other features of significance for the scatter were model complexity and purpose, and different interpretations of the model assumptions. The results from RIDYFOM and SPOP compared well with those from other models.

Due to work necessitated by the Chernobyl accident the planned comparisons between model predictions and fallout data from Norway, Finland, and Sweden were not made. However, the accident has caused an enormous increase in the amount of data available now, which permits a much more comprehensive and reliable modelling to be made.

The situation after the Chernobyl accident has caused experimental data on radioactivity in the environment to become abundant. However, it is important that data used for modelling be examined carefully, so that only results of acceptable quality are being used. Furthermore, the opportunity will be used to investigate possible differences in the transfer in the terrestrial environment of radionuclides between those from Chernobyl accident and those from global fallout from the atmospheric nuclear weapons tests.

## 3.3. Uptake and loss of certain transuranium-, fission- and activation nuclides by Mytilus and Fucus

A technique regarding the handling of Fucus vesiculosus plants in field experiments proved very successful in a long-term experiment on in-situ loss rates. Branches of young plants were fixed on pieces of string and tied up between the framework of a wellbox allowing adequate water movements. The plants survived and grew throughout the experimental period from June 1985 till November 1986. Multielement radioisotope tracer techniques utilizing gamma- and alpha-spectrometry were used for the analyses.

A long-term loss-rate experiment with Mytilus edulis and Fucus vesiculosus initiated in June 1985 in Oskarshamn on the Baltic coast was running until November 1986. The analytical work has not yet been terminated, but preliminary results suggest that initial loss rates were faster than in the earlier Baltic mussel experiment.

Verification of the model SENSI describing accumulation and loss of radionuclides in Fucus has been further improved by applying results from monthly field-samples and monthly discharge rates from a nuclear power plant over 3 years.

Results from the mussel experiment in the Forsmark Biotest Basin in 1983-84 were published in 1986. It was concluded that the distinct seasonal variation observed in the loss rates for all 10 elements studied could not be explained by temperature effects but rather by seasonal variations in food availability. Plutonium to americium ratios decreased during the depuration. The plutonium fraction lost after 300 days was twice the corresponding fraction of americium. In this experiment, americium and europium behaved as analogues.

## 3.4. Determination of less well-known long-lived radionuclides

An analytical procedure based on concentration of actinides from 1800-litre seawater samples by hydroxide precipitations has been developed. Neptunium is isolated by ion exchange, flouride precipitation and extraction with TTA. As a radiochemical yield determinant $^{239}Np$ or $^{235}Np$ is used. Neptunium is electroplated onto stainless steel discs before α-spectrometry counting for about 10 days. The procedure allows for sequential separation of Pu, Am, Tc, and radiocesium together with Np.

In Am analysis on samples contaminated by the Chernobyl debris $^{242}Cm$ and $^{244}Cm$ have been measured by α-spectroscopy.

The radiochemical yield of Np is 20-50%. The procedure has been applied with success on several samples contaminated with $^{237}Np$ at fallout or close to fallout levels. In surface seawater from the Barents Sea the $^{237}Np$ concentration is 0.4-1.0 mBq $m^{-3}$ or 4-10% of the $^{239,240}Pu$ concentration. In the northern North Sea concentrations up to 10 mBq $m^{-3}$ $^{237}Np$ have been measured.

The sequential separation of Tc and transuranics have recently been tested on seawater samples from the Baltic Sea with Tc-yields at about 60%.

$^{99}Tc$ has been carried out on Chernobyl debris. However, the method used does not decontaminate efficiently for ruthenium isotopes, which are abundant compared to Tc in the debris. This has been shown by recounting the samples half a year after the first measurement.

## 3.5. Studies of transuranic elements, radiocesium, tritium and $^{60}Co$ in seawater sediments, seaplants and mussels in the North Atlantic region

In 1986 the Chernobyl accident seriously perturbed the field studies. The radiocesium tracers discharged from European reprocessing plants can probably no longer be used for oceanographic tracer experiments. After the Chernobyl accident seawater samples were collected in May and August in the Danish Straits. A joint German-Nordic cruise on board the F/S Gauss was carried out in the Baltic Sea in October. Furthermore, FPS Walter Herwig collected a number of seawater samples in the East Greenland Current.

The analysis of transuranics in seaweed from the French Channel Coast shows similar distance relations as seen for $^{99}Tc$. The activity concentrations are inversely proportional to the square root of the distance in km from the source (Cap de la Hague in France). The measurements of Chernobyl debris in the Danish Straits showed that the radiocesium was mixed in the water column (20-30 metres depth) in approximately 4 months. The Gauss cruise in October showed the highest water concentrations (~ 700 Bq $m^{-3}$ $^{137}Cs$) off the east coast of central Sweden (Gävle). Sediment samples collected in the southern part of the Baltic Sea did not show Pu debris from Chernobyl (the $^{238}Pu/^{239,240}Pu$ ratio in the samples was similar to that in global fallout).

Measurements of soil samples from the Faroe Islands and Greenland provided estimates that the NE Atlantic has received 5-50

PBq $^{137}Cs$ from the Chernobyl accident. The total discharge from Sellafield is approximately 32.5 PBq (decay corrected to 1986). Hence the contribution of $^{137}Cs$ from Chernobyl to the Atlantic Ocean may be on the same order of magnitude as that from Sellafield. In cooperation with the University of Lund, Sweden the NRPB-box model for the north-eastern Atlantic has been improved by using existing radiocesium data, and will be applied in the EEC MARINA-project.

## 3.6. Environmental studies of plutonium and americium at Thule, Greenland

Speciation studies have been carried out in the IAEA laboratory for Marine Radioactivity in Monaco. Sediment samples collected in 1968 and in 1984 were used for the studies. Five fractions of the Pu and Am activity were made:

1: exchangable; 2: bound to carbonates; 3: bound to Fe-Mn oxides and hydroxides; 4: bound to organic matter; 5: residual.

The most remarkable observation of this speciation study was that the Pu activity had apparently not changed with respect to physical-chemical characteristics from 1968 to 1984. This implies that, e.g. no increasing availability of Pu with time has been observed in the Thule sediments.

The studies of sedimentation rate and bioturbation have been carried out in the Bedford Institute in Canada, but the results are not yet available.

## 3.7. Long-term tagging of elvers, Anguilla anguilla, with radioactive europium

What happens to larval or small post-larval fish that are set out in the environment to secure a natural population? Do they ever reach maturity in amounts large enough to influence fishery in practice? In order to answer these questions one needs a

fish mark that can be introduced through food or water and which will follow the animal during a major part of its further growth.

Elvers were labelled with $^{152}Eu$ and $^{155}Eu$. Optimum conditions turned out to be incubation for 3 hours at 15°C in artificial seawater containing 2% NaCl and 0.1% KCl, $EuCl_3$ at 1 mCi (37 MBq)/l and an eel concentration of about 15%. Laboratory experiments pointed to a biological half-life of added europium of 1.6± 0.5 years.

1300 $^{155}Eu$-labelled elvers (50 Bq/eel), each weighing on the average 0.21 g, were set out near Oskarshamn on the east coast of Sweden in June 1982. Three of these were caught nearby in May 1985, one was caught in August 1985 and four were caught in April 1986. By then the average weight was 56 g (1985) and 76 g (1986) and the material showed no significant loss of label other than radioactive decay.

## 3.8. Membrane lipids in the eel, Anguilla anguilla, affected by environmental factors

This project aims to study the mechanism of salt transport in marine animals and how this mechanism is affected by various environmental factors.

Recent results can be summarised as follows:

1) Incorporation *in vivo* into tissue lipids of [1-$^{14}C$] acetate added to the water in the incubation tank showed the same relative distribution pattern of $^{14}C$-activity among various phospholipids in the gills, the esophagus and the intestine, when the eel was incubated in seawater; in fresh water this pattern was found only in the intestine, while both the gills and the esophagus showed a relative excess of $^{14}C$-label in phosphatidylethanolamine (PE).

2) Similar studies with [ $^{32}P$] phosphate also showed a relative excess of [ $^{32}P$] PE in both the gills and esophagus in fresh water compared to seawater, and no such difference in the intestine.

3) As long as the labelled precursors were added to the water in the incubation tank both [ $^{14}C$] PE and [ $^{32}P$] PE were not identical to unlabelled PE on thin-layer cromatograms, and the $^{14}C$-labelled lipids contained predominantly $C_{16:1}$ and $C_{18:1}$ fatty acids.

4) However, when the two precursors were injected directly into the eel there was no longer any marked difference between the distribution patterns of radioactivity among gill phospholipids in fresh water and seawater; there was no longer any difference between labelled and unlabelled PE on thin-layer chromatograms, and the $^{14}C$-labelled gill lipids contained predominantly $C_{16:0}$ and $C_{18:0}$ fatty acids.

5) The corresponding liver lipids were affected neither by a change in environmental salinity nor in precursor application.

We atribute those results to a specific labelling of lipid metabolism in the mitochondria-rich chloride cell when the precursors are added to water in the incubation tank.

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# 4. ELEMENTS OF RISK BY NUCLEAR ACTIVITIES

## 4.1. Puff dispersion model

A new model PUFFCON is being developed for calculating the consequences of accidental releases taking into account the variation of the meteorological conditions with time. This model is based on a puff dispersion model. It is a three-dimensional computer model which simulates the release of pollutant puffs and predicts their concentration as they diffuse while being advected downwind by a time- and space dependency. This work is partly financed by the Nordic Council of Ministers.

In 1986 models for calculation of doses from releases of radioactive material has been included in PUFFCON. Doses to individuals as well as collective doses from the three dose components: inhalation, external gamma rays from airborne radioactivity and gamma rays from deposited activity can be calculated.

A scheme for calculating puff diffusion in complex terrain has been implemented.

A prototype for an on-line version of PUFFCON has been implemented. The model could be used for monitoring the dispersion of material released in an accident in real time.

The computer programs for calculating concentrations of airborne material and for graphical presentation of calculation results have been further developed.

The puff-dispersion model, RIMPUFF, has participated in a benchmark study initiated by Kernforschungszentrum Karlsruhe (KfK). The study aims at quantifying strengths and weaknesses of more complex models. For this purpose, tasks for deterministic and probabilistic calculations have been defined.

The comparison of the probabilistic calculations is carried out on the basis of concentration, organ dose and consequence distributions obtained with an improved version of the ACA-code UFOMOD (ACA = Accident Consequence Assessment). The input data to UFOMOD are integrated air and ground concentrations for three different isotope types and four release phases. The meteorological data are hourly observations of wind speed, wind direction, stability and rain intensity for 45 weather stations around the site of Biblis B (south of Frankfurt). A total of 48 representative weather sequences have been selected for the calculations. The calculations with RIMPUFF are partly financed by the CEC.

PUFFCON has been used for the Danish Nuclear Inspectorate in calculating the consequences of accidental releases from nuclear power plants close to Denmark.

## 4.2. Radiological consequences of accidental contamination in urban environments

The areas for which major uncertainties exist for predicting radiological consequences of accidental releases of radioactivity especially concern the urban agglomerations.

As part of the CEC research programme MARIA (Methods for Assessing the Radiological Impacts of Accidents) and of the Nordic cooperation in nuclear safety, the department studies radioactive contamination with special emphasis on urban environments.

### 4.2.1. External deposition

The first cloud from Chernobyl arrived over Zealand at noon Sunday, April 27th and passed the area during the following day under dry weather conditions. The weather stayed dry a full week. This presented an unique opportunity to measure

the dry deposition velocity on different urban surfaces. During the time where the deposition took place the weather remained stable with a mean wind speed of 3 m/s and Pasquill stability category of B-C. Samples of plastered walls, roof material, street concrete flagstone, road asphalt, and grass were collected and measured for their content of radioactive material. In order to find the dry deposition velocity on these surfaces the air concentration must be used as a reference. This reference had been chosen as the amount of material collected on a Whatman glass-fiber filter filtrating the air 1 m above a grass field in the vicinity of the town where the samples were collected. As only a part of the total iodine in air can be collected on the glass-fiber filter a triple filter arrangement was set-up in order to find the component distribution of $^{131}I$. This arrangement consisted initially of glass-filter paper (containing 38% of the iodine) followed by a KI-prepared filter (11%) and finally a charcoal bed (51%). However, this was operated after the collection of the samples; therefore, it gave merely an indication of the distribution during the first episode. The results are summarised in the following table:

Dry deposition velocity in cm/s

| | Iodine (excluding organic components) | Non-reactive particles |
|---|---|---|
| Smooth surfaces (walls, roads, etc.) | 0.02-0.03 | 0.001-0.004 |
| Rough surfaces (corrugated roofs) | 0.2-0.4 | 0.03-0.05 |
| (grass) | 2 | 0.03-0.05 |

4.2.2. Ventilation, filtering, and internal deposition

The relation between the time-integrated air concentration indoors to that of outdoor air (the transfer factor, D, from the outdoor exposure integral to that indoors) was measured during the Chernobyl release by placing a double-filter arrangement consisting initially of glass-filter paper followed by a charcoal bed outside and inside the building. The results are shown in the following table.

The transfer factor D from outdoors to indoors

| | Glass filter paper | Charcoal bed |
|---|---|---|
| I-131 | 0.39 | 1 |
| Cs-137 | 0.27 | Below Detection Limit |
| Be-7 | 0.49 | Below Detection Limit |

The deposition velocity indoors with reference to the outdoor concentration was measured on different internal surfaces. The results are summarized in the following table.

Dry deposition velocities on internal surfaces in cm/s

| | Iodine (excluded organic components) | Non-reactive particles |
|---|---|---|
| Horizontal surfaces | 0.002 | 0.0005-0.0013 |
| Vertical surfaces | 0.001 | 0.0001-0.0002 |

### 4.2.3. Run-off from roofs

Run-off from roof material has been measured during the Chernobyl release. The roof materials under investigation were cement tile (45° slope), red tile (45°), corrugated raw eternite, and silicon-treated eternite (45° and 30°). Essentially no retention of iodine was found, except in the case of red tile where about half of the material stayed on the roof. Most of the ruthenium (90-100%) was also removed with the run-off water when considering the slope of 45°, except for red tile where half of the ruthenium remained. The retention was higher when considering a 30° slope where about 30% of the material stayed on the eternite roof. For cesium the situation was quite different as about 90% of the cesium in the rain was trapped on the roof, except for silicon-treated eternite, where only one-quarter of the cesium stayed on the roof when considering a roof with both 45° and half when considering 30° slope.

### 4.2.4. Shielding factors for plume radiation

An existing model for calculating the dose rate from a passing plume (bi-variate Gaussian distribution) is being further developed so indoor dose rates can be calculated. The plume is subdivided in small sub-volumes and the dose contribution from each is integrated over the significant plume volume. The $\gamma$-radiation from the sub-volumes will be attenuated because of both geometrical spreading (inverse square law) and interaction processes (exponential attenuation) in air and building materials. The dose contribution from scattered photons is accounted for by the approximate dose buildup factor method.

So far the effort has been concentrated on development of a mathematical description of the thickness of the building material along the vector from the plume sub-volume to the detector point inside the building. The buildings are considered as boxes with a variable thickness of walls and floors/ceiling.

Complex buildings will be described as a composite of boxes. As a first approximation, the window apertures are accounted for by the "window-smearing" method, i.e. the outer wall thickness is reduced in an appropriate manner.

## 4.3. Work for the Swedish State Power Board

The Swedish State Power Board wanted a method for calculating radiation doses in the surroundings of nuclear power plants after severe accidents.

A specified accident at Ringhals 1 were chosen as example. A typical weather condition was stated as Pasquill D with wind speed 8 m/s, and an extreme one, Pasquill F with wind speed 4.8 m/s.

A preprint of a report was issued in July. It dealt with a theoretical core meltdown accident at one of the Barsebäck reactors with filtered venting through the FILTRA plant. The Swedish National Institute of Radiation Protection commissioned a calculation of collective doses as an addition to this report.

In December 1986 a preprint of a report dealing with a theoretical core meltdown accident at Forsmark reactor No. 3 was finished. The assumptions used for the calculation were a 0.06% release of iodine and cesium corresponding to a 0.1% release through the FILTRA plant at Barsebäck. As a typical weather was chosen Pasquill D with wind speed 5 m/s and as an extreme weather, Pasquill F with wind speed 2 m/s.

The calculations were made by means of the PLUCON 4 code.

## 4.4. Computer modelling of radioactive source terms at a Tokamak reactor

Risø interactive graphics system has now been included in the MCNP (Monte Carlo Neutron Photon) code. This has solved a lot of geometrical problems and a complete geometrical model of the NET III A shielding construction has been developed.

To determine the complete photon radiation field it is necessary to calculate both the time and geometrical distributions of the neutron activation products in the construction materials. Therefore, the MCNP code has to be extended for extraction and mathematical treatment of the relevant output data concerning the radionuclide distributions. These output data will recurrently be used as new input data for MCNP. So far, the extraction part has been developed.

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## 5. NUCLEAR EMERGENCY PREPAREDNESS

### 5.1. Chernobyl

At about 10 a.m. on Monday 28 April 1986 a surprisingly high content of radioactive substances was observed in a grass sample collected from the area of Risø National Laboratory. The measurement was performed as part of the routine surveillance of the radioactivity levels at Risø and in its surroundings.

Additional measurements including measurement of a new grass sample at 11 a.m. confirmed the correctness of the initial measurement. Immediate action was taken in order to identify the origin of the enhanced radioactivity. It was believed at first that the radioactivity might have been released from one of the nuclear installations at Risø.

However, it was told from Sweden that enhanced radioactivity levels also had been measured in Sweden and in Finland. No disturbances were reported from the Swedish and Finnish nuclear power plants. Taking into account the prevailing easterly wind it was concluded that a widespread pollution had occurred and that its origin was located east of Finland.

An immediate evaluation of the degree of contamination was based on measurement results from the grass samples and from an air sample filter which had been in use since 24 April. Already at that time it was estimated that the pollution of the surface of the earth and of the air did not infer that there was a notable health risk.

On the basis of the preliminary measurements it could be inferred that the pollution most likely came from a nuclear reactor accident.

The accident in the Chernobyl nuclear power plant was announced in the Danish news media at about 7 p.m. of that same day.

The variation of the external radiation with time was determined by means of an ionization chamber placed outdoors in the Risø area. This highly sensitive instrument is designed for determining low-level background radiation. The readings of the instruments (Figure 3) show a rise in the radiation level of about 10% of the background level in the afternoon of the previous day succeeded by a gradual decrease over the next three days down to normal background level. Further, the readings indicate that the plume of radioactive contamination arrived at the Risø area at noon on Sunday 27 April.

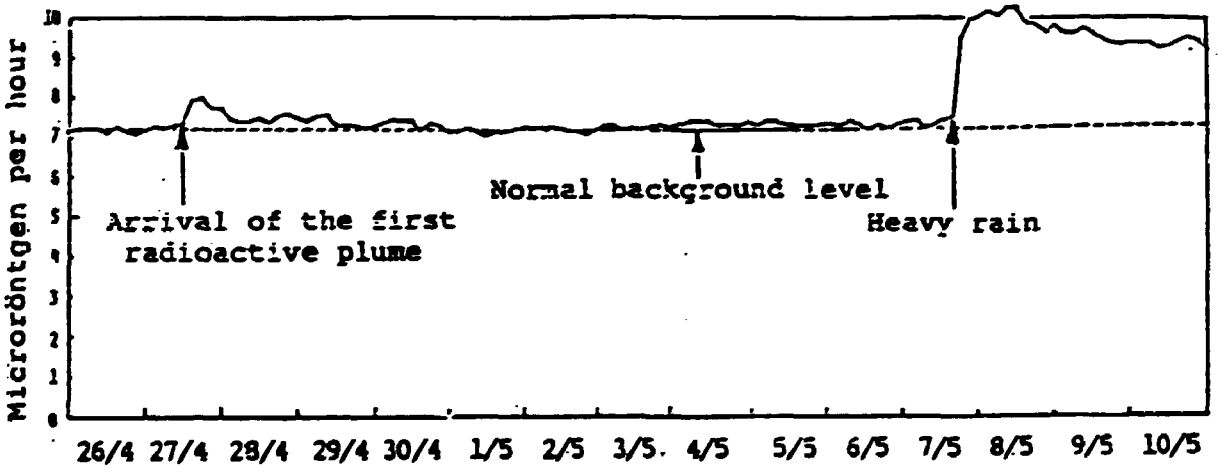


Fig. 3. External gamma radiation measured at Risø.

In connection with heavy rain the external gamma ray intensity increased during the evening of Wednesday 7 May to 10.3 μR/h, which is about 50% higher than the normal background level. The total radiation impact (including future radiation exposures resulting from the Chernobyl accident) has been estimated to correspond to a few weeks of natural background radiation.

Thursday 1 May a coordinating group was established under the Danish Environmental Protection Agency with representatives from the National Board of Health, National Food Agency, Risø National Laboratory, Civil Defence, Meteorological Institute and Ministry of Foreign Affairs.

Risø took part in the monitoring of the environment and of foodstuff and also assisted in answering questions from the media and the public.

A monitoring programme was agreed upon for the period 1 June - 30 September and another for 1 October 1986 - 30 September 1987. The Health Physics Department was asked to carry out the measurements under this programme cf. 3.1. Further, the department has undertaken to monitor samples of imported and exported foodstuff.

The scientific outcome of the accident is reported elsewhere in this report.

## 5.2. Barsebäck power plant

On 19 November a Swedish-Danish Barsebäck emergency exercise took place, held as a one day staff drill focusing on the information problems encountered.

Routine training of staff members to the technical evaluation center has been performed through the year.

## 5.3. ARGOS system

The ARGOS (Accident Reporting and Guiding Operational System) is a computerized system for communicating and presenting monitoring data and related dose calculations. The system is developed in cooperation with the Danish Environmental Agency.

The system has been reviewed for more stable performance. A translation into the C programming language is started in order to permit installation on other hardware e.g. personal computers and VAX.

## List of publications

AARKROG A. Slutrapportering af Risøs måleprogram (Fase II) i forbindelse med Chernobyl-ulykken (in Danish), Risø, January 1987.

AARKROG A. Chernobyl monitoring data compiled by Risø National Laboratory by January 30, 1987 (Appendix in English to the above mentioned Danish report), Risø, January 30, 1987.

Appendix 1.

STAFF OF THE DEPARTMENT

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(number refers to the relevant sections of this report)

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Appendix 2.

PARTICIPATION IN INTERNATIONAL WORKING GROUPS, etc.

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Advisory Group on Post-Accident Assessment and Recovery Operations in a Radiation Environment (Hedemann Jensen).

OECD, Nuclear Energy Agency

Committee on Radiation Protection and Public Health (Gjørup)

Committee Core Task Group, CRPPH/ICRP Interaction (Gjørup)

CSNI: Principal Working Group IV (Gjørup)

do. Subgroup of Experts on Accident Consequences (Thykier-Nielsen)

CSNI: Working Group on Fuel Cycle Safety (Roed)

Executive Group for Research on Sea Disposal of Radioactive Waste (Aarkrog)

do. Radiological Surveillance Task Goup (Dahlgaard)

Commission of the European Communities

Article 31 Committee, Basic Safety Norms (Gjørup)

Article 31 Working Group concerning Sellafield (Gjørup)

Article 37 of the Euratom Treaty, Group of Experts (Walmod-Larsen)

CGC on Radiation Protection (Gjørup)

do. Expert Group C on the Atmospheric Fission Product Dispersion following a Reactor Accident (Thykier-Nielsen).

Expert Group on Safety and Environment for the European Fusion Programme (Warming).

Expert Group on Transfrontier Emergency Planning (Walmod-Larsen)

Group of Technical Experts on Radiation Protection Dosimetry (Christensen and Majborn)

EURADOS-CENDOS, Beta- and Low-Energy Photon Dosimetry (Christensen)

EURADOS-CENDOS, Personal TLD Dosimetry (Christensen)

European Atomic Energy Society:

Public Relations Correspondents Group (Walmod-Larsen)

International Committee for Radionuclear Metrology (S.P. Nielsen)

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SNODAS (coordination of Nordic dose calculations and atmospheric dispersion models) (Hedemann Jensen, Thykier-Nielsen)

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The main emphasis in the report has been placed on scientific and contractual work. However, service functions do constitute a substantial work load for the department.

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